



Species recognition in the genus *Scolothrips* (Thysanoptera, Thripidae), predators of leaf-feeding mites

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Abstract

Species of the genus *Scolothrips* are re-assessed based on examination of type material together with many other specimens, and a key is provided to identify the 14 species recognised. The possibility is discussed that the three North American species, *hoodi*, *pallidus* and *sexmaculatus* are colour variants of a single species. Three apparently Old World species, *dilongicornis*, *longicornis* and *takahashii*, cannot be distinguished satisfactorily. Three new synonyms are established: *quadrinotata* is a synonym of *asura*; *hartwigi* is a synonym of *brevipilis*; *priesneri* is a synonym of *takahashii*. Two species from the Canary Islands are considered *nomina dubia*: *quadrimaculatus* and *lazarotensis*. Two species are here recorded for the first time from Australia, *latipennis* and *rhagebianus*, and Australian records of *sexmaculatus* are considered to be based on misidentifications.

Key words: Six-spotted thrips, *Scolothrips sexmaculatus*, mite predators

Introduction

Species of the thripid genus *Scolothrips* are well known as predators of mites on the leaves of plants (Gilstrap 1995), and under the name “six-spotted thrips” these insects are sometimes marketed as biocontrol agents. Recognition of an adult thrips as being a member of the genus *Scolothrips* is particularly easy, due to the presence of six (rarely five) pairs of exceptionally long setae on the pronotum as well as a similar pair arising between the ocelli. However, recognition of species within the genus has remained difficult (Bhatti & zur Strassen, 2009), including three that are well-known in North American entomology (Stannard, 1968). The problem is that some species have been distinguished on small details of body and wing colour, and lengths of antennal segments and setae. The recorded differences between species are often slight, and authors rarely indicate how many specimens were measured, nor if these came from one or multiple samples. It is thus not possible to evaluate the statistical or biological significance of many published observations. Hoddle *et al.* (2008) suggested some of the recorded differences might result from environmental conditions during larval development, such as temperature or the mite species consumed. As discussed below, the most frequently recorded species belong in one of two species-groups, the *sexmaculatus* species-group, and the *longicornis* species-group. Each of these comprises three nominal species that are distinguished from each other on character states for which there is little evidence of reliability.

Technical problems

The identification of *Scolothrips* species remains based on slide-mounted museum specimens, many of which are in an unsatisfactory condition and with little or no host data. Most slide preparations of *Scolothrips* species in museum collections are uncleared, usually falling far behind the technical standards developed by several recent workers (see Okajima, 2006; Hoddle *et al.*, 2008). In most such specimens, iridescence from the body contents makes it difficult, sometimes impossible, to see surface details of sculpture and chaetotaxy, or even the extent of dark markings on the yellow bodies. Because of this, the major taxonomic reference work on this genus (Priesner,

1950) relies heavily on character states based on colour to distinguish species. For accurate identification and taxonomic study, good reference specimens of *Scolothrips* (Figs 2, 3) can be prepared by floating individuals on the surface of a 2% solution of sodium hydroxide for a few hours, such that the wings are caught in the meniscus. These specimens are then washed in water prior to a standard dehydration schedule and mounting procedure (Hoddle *et al.*, 2008). This process removes the body contents, thus rendering the shaded markings on the body surface more obvious, but without destroying the markings themselves. Body colour patterns can also be studied on freshly collected specimens in ethanol, or on specimens mounted into one of the water-soluble mountants (Fig. 8), but can be particularly obvious on un-macerated specimens when examined in clove oil just prior to being mounted into Canada balsam (Fig. 7).

Historical problems

Priesner (1950) provided a key to the 13 species that he recognised. However, there are serious problems with that key. The first major couplet (2 versus 9) distinguishes species with pale setae from species with at least some setae shaded. Not only is this particularly difficult to assess, but *indicus* and *rhagebianus* fall in opposite sides of the key although they are now regarded as the same species. Several other couplets similarly involve equivocal character states. Moreover, internal evidence suggests that two previously described species, *lanzarotensis* and *quadrifasciatus*, were included in the 1950 key without access to specimens (see below). Subsequent to that 1950 publication, a further six species were described in this genus: Sakimura (1954); Han & Zhang (1982); zur Strassen (1965, 1993); Mound *et al.* (2010). A key recognising six species from Europe was provided by zur Strassen (2003), but details in that key of *lanzarotensis* and *quadrifasciatus* are derived from the original 1933 descriptions (see below).

An added complication is provided by the history of the most widely used specific epithet in the genus, *sexmaculatus* Pergande. Since this is also the type species of the genus, Priesner (1950) attempted to stabilise the use of the name. He based his interpretation of the species on specimens sent to him by S.F. Bailey that had been collected from “peach leaves, Empire, California, 14.ix.1949, coll. F. Summers”. However, Stannard (1968) subsequently selected as Lectotype a specimen from Pergande’s original type series, although he provided no morphological details of this specimen. These specimens have been examined and are discussed below.

Present objectives

The initial objective of the present study was to provide names for the *Scolothrips* species found in Australia, where the name *sexmaculatus* has been in use for many years (Kelly & Mayne, 1934). However, because of the possibility that some species may have been widely transported around the world, this required that all of the previously described species be studied, a task made possible only through the courtesy of many colleagues. Studies on the various type specimens, particularly those of Priesner in the Senckenberg Museum, suggested new interpretations of the identity of several described species. The Lectotype of *sexmaculatus* was examined on loan from the US National Museum of Natural History, and compared with the specimens used by Priesner to re-describe this species. Examination of the type specimens was carried out in the context of studying large numbers of *Scolothrips* specimens from the University of California, at the Bohart Museum, Davis (Bailey Collection, UCD), and the Entomology Research Museum, Riverside (Ewart Collection, UCR), as well as extensive collections of this genus in the three major collections in Australia. The result is not a formal taxonomic revision, but is presented as a functional identification key to the species of *Scolothrips* worldwide.

Acknowledgements and depositary abbreviations

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Museum, London (BMNH); David Nickle curator of the thrips collections belonging to the US National Museum of Natural History, Washington DC (USNM); Penelope Gullan and Steve Heydon at the University of California, Davis (UCD); Mark Hoddle at the University of California, Riverside (UCR); Peter Gillespie at the Department of Agriculture, New South Wales, Orange (NSWO); Desley Tree at the Department of Agriculture, Queensland (DAQ); Paul Tinerella at the Illinois Natural History Survey (INHS). Mark Hoddle kindly organised shipment to Canberra of freshly preserved specimens of *sexmaculatus* from commercial suppliers of biocontrol agents in California. Hong-rui Zhang of Yunnan Agricultural University, and Li-hong Dang of the Institute of Zoology, Beijing, kindly helped with translations of works by Yun-fa Han. The manuscript was improved through the advice and criticisms kindly provided by three anonymous referees.

Key to species (females)

[Excluding *quadrinotatus* and *lanzarotensis*—see below]

[* see discussion under *longicornis*]

1. Body strongly bicoloured, dark brown and white, with red internal pigments; metanotum with linear sculpture (Fig. 1) 2
- . Body almost unicoloured, mainly white, yellow or light brown; metanotum with reticulate sculpture (Figs 2, 3) 3
2. Ocellar setae I and II absent; antennal segments III–IV and V–VI broadly joined (Fig. 4); Australia *ochoa*
- . Ocellar setae I and II present; antennae slender (Fig. 5); tropical Asia and Australia *asura*
3. Pronotum without a pair of posteromesad discal setae (Fig. 2); fore wing with sub-basal dark band fully including costal margin of wing 4
- . Pronotum with at least one pair of posteromesad discal setae (Fig. 3); fore wing sub-basal dark band not including costal margin, or fore wing pale with no dark bands. 9
4. Fore wing clavus shaded only at extreme base 5
- . Fore wing clavus more extensively shaded, with apex or posterior margin pale 6
5. Head, thorax and abdomen entirely yellow; Cape Verde Is *moundi*
- . Body yellow, head with weak shading, lateral sclerites of pterothorax brown (Fig. 6); Yemen, Sudan, Transvaal. . . . *brevipilis*
6. Pterothorax brown or shaded laterally; abdominal terga uniformly; but sometimes weakly, shaded 7
- . Pterothorax not shaded laterally, abdominal terga yellow 8
7. Fore wing transverse bands sharply defined, costal area not shaded basal to first dark band; fore wing clavus shaded with apex pale; pterothorax strongly shaded laterally, pronotum and abdomen equally yellow; male macropterous; widespread in Mediterranean region. *latipennis*
- . Fore wing transverse bands diffuse, costal area basal to first dark band also weakly shaded; fore wing clavus shaded to apex with only posterior margin pale; pterothorax weakly shaded laterally, pronotum much paler than shaded abdomen; male apterous; on *Juniperus* in northern Europe *uzeli*
- 8*. Metascutum shaded; male fully macropterous; Taiwan, Hawaii *takahashii*
- . *. Metascutum yellow; male hemimacropterous; Europe *longicornis*
- . *. Metascutum yellow; male micropterous; China *dilongicornis*
9. Fore wing pale with no dark bands; Canary Is; Cape Verde Is. *tenuipennis*
- . Fore wing with dark cross bands 10
10. Abdominal terga III–VI with pair of dark spots anterolaterally (Fig. 8), median shaded areas variable but not extending to tergal posterior margins; metascutum mainly pale, metascutellum dark; Old World sub-tropics. *rhagebianus*
- . Abdominal terga III–VI median area shaded or pale (Fig. 7), without isolated lateral dark spots; metascutum pale or dark; Nearctic 11
11. Body completely pale with no dark or shaded markings, metascutellum as pale as rest of body *pallidus*
- . At least terga II–IV shaded medially, metascutum and metascutellum distinctly grey 12
12. Abdominal terga uniformly light greyish-brown across almost full width. *hoodi*
- . Abdominal terga II–IV shaded medially but yellow laterally, terga V–VII usually pale or with weak shading . . . *sexmaculatus*

Scolothrips asura Ramakrishna & Margabhandu 1931: 1035

Scolothrips quadrinotata Han & Zhang 1982: 56 **syn.n.**

Described from India, this strongly bicoloured species is sometimes taken from field crops, and is known from Thailand, Taiwan, Ryukyu Is (Japan), and northern Australia. There is nothing in the description of *quadrinotata* to distinguish it from *asura*, and Han (1997) indicated that he had described the species based on comparisons to details of setal lengths published by other authors, not by examining specimens. The head, metathorax, and abdominal segments I–II and VI–VIII are brown with bright red internal pigment in life. In contrast, the legs, pronotum

and abdominal segments III–V are yellow, although segments IX–X vary from brownish yellow to brown. On the fore wing, the first dark band extends to the base of the wing and includes the clavus. The metanotal sculpture is similar to that of *ochoa* (Fig. 4), in contrast to the other species in the genus, but the antennae (Fig. 5) resemble those of typical *Scolothrips* species.

***Scolothrips brevipilis* Priesner 1936: 83**

Scolothrips hartwigi Priesner 1950: 53 **syn.n.**

At the time that Priesner described *hartwigi*, he knew *brevipilis* only from a single poorly preserved male that had been collected in Sudan. In contrast, the interpretation of *brevipilis* here is based on a series of both sexes from Yemen identified by Richard zur Strassen (in SMF). This is a distinctively coloured species (Fig. 6), with the sides of the pterothorax and associated internal apodemes brown in contrast to the yellow body. The new synonymy indicated here is based on a comparison of the specimens from Yemen with the types of *hartwigi* from Transvaal, South Africa, together with specimens collected subsequently in that area (in SMF).

***Scolothrips dilongicornis* Han & Zhang 1982: 56**

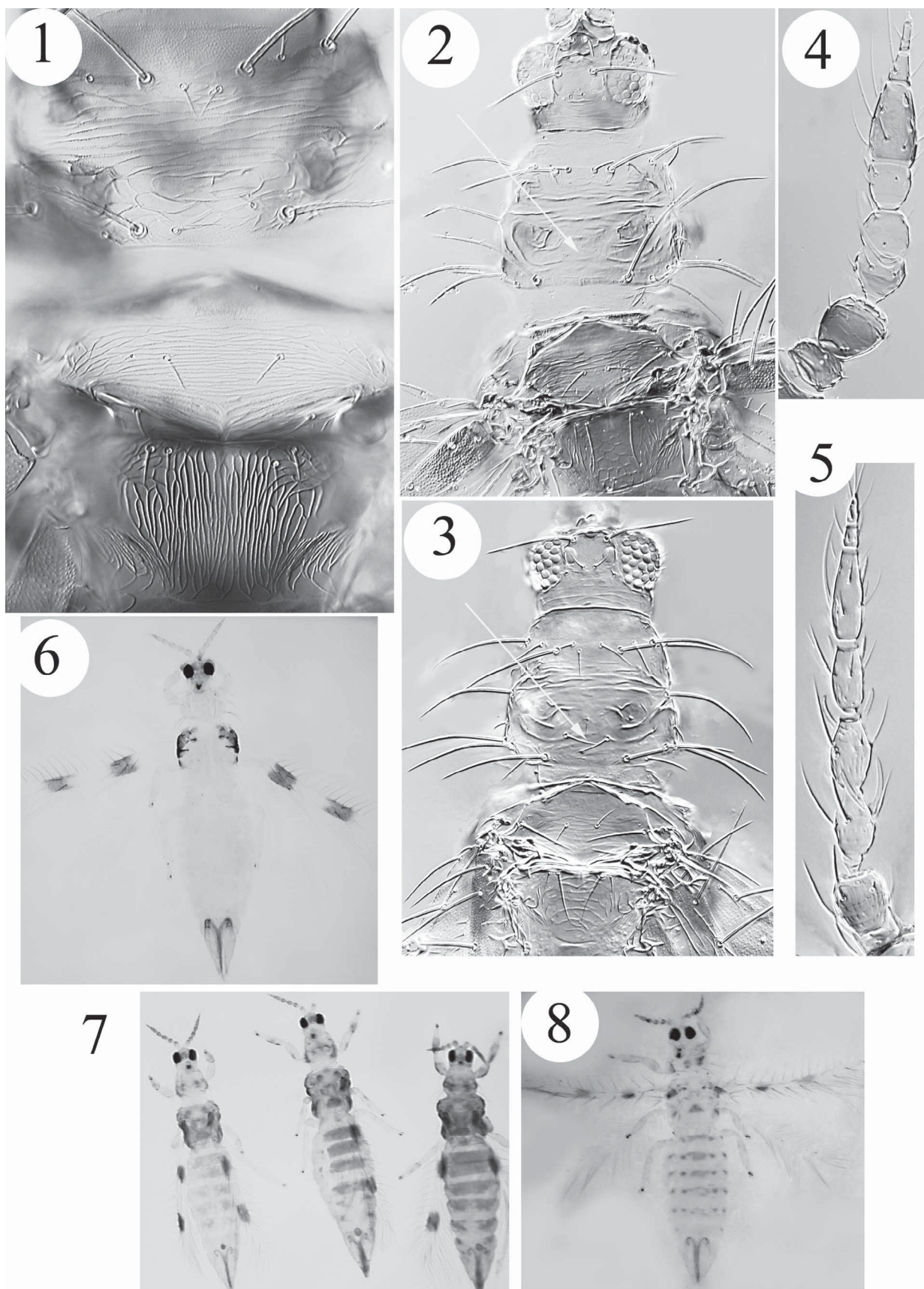
Described from specimens taken in Beijing, China, feeding on red spider mites on apple leaves, several of these original specimens have been examined. At present they cannot be distinguished satisfactorily from *longicornis*, as discussed further below.

***Scolothrips hoodi* Priesner 1950: 45**

Described from Plummers Island, Maryland, this species was recorded from Illinois by Stannard (1968) from *Juniperus virginiana* and *Taxus canadensis*. The male is unknown, and for the present study one paratype (in SMF) and two females identified by Stannard (in INHS) have been examined. The significance of this species remains unclear. The lengths of the major setae are at the lower end of the range that can be found amongst individuals of *sexmaculatus*, but it is possibly a darker (?low temperature) form of *sexmaculatus* (see below). The extensive body shading is reminiscent of the European species *uzeli*, a species that lives on *Juniperus*. However, *uzeli* is not closely related, with the pronotum lacking a pair of discal setae and the fore wing clavus shaded at the apex.

***Scolothrips lanzarotensis* Priesner 1933: 194**

Described from the Canary Islands, the three females on which this species was based are not in the Senckenberg Museum (nor are any specimens of the other species described in that 1933 paper). Priesner stated that only further specimens would confirm if *lanzarotensis* was a valid species, and indicated (in 1950: 56) that the species “comes near *latipennis*”. Despite this, Priesner appears to have produced the 1950 key to species without access to the type specimens of *lanzarotensis*, judging from the statement that the presence or absence of pronotal discal setae is “unknown”. Two females have been studied (in SMF) that were collected in 1964 in Tenerife. These were identified as *lanzarotensis* by Richard zur Strassen from information in the original publication, and the species was apparently included in the key to European species (zur Strassen, 2003) on the basis of these two specimens. The three differences from *S. latipennis* quoted in that key are all associated with body size, and an alternative interpretation would be that these specimens are small individuals of the more widespread *latipennis*. It should be noted that Priesner (1933) states “Vorderandborsten des Prothorax 78-90” whereas zur Strassen (2003) states “Anteromarginale Borsten S1 des Pronotum 36-41”. However, it is not clear if these two authors were referring to precisely the same setae. In the absence of the original specimens, *lanzarotensis* is here considered a *nomen dubium*.



FIGURES 1–8. *Scolothrips* species. (1) *S. ochoa*, pro, meso and metanota. Head and thorax 2–3 (arrow indicates position of posteromesad discal setae); (2) *S. latipennis*; (3) *S. sexmaculatus*. Antenna 4–5: (4) *S. ochoa*; (5) *S. asura*. (6) *S. brevipilis* (in Canada balsam). (7) *S. sexmaculatus* (in clove oil). (8) *S. rhagebianus* (in Hoyers mountant).

***Scolothrips latipennis* Priesner 1950: 54**

The type specimens of this species (in SMF) were collected at Cairo, Egypt feeding on *Eotetranychus cucurbitacearum* (Tetranychidae) on *Citrullus* leaves. It was noted at that time that *latipennis* sometimes co-existed on the same leaf as *Scolothrips longicornis*, and collections from Egypt in 1987 from soy bean leaves confirmed this association (in BMNH). These two species are readily distinguished from *sexmaculatus* because the pronotum lacks a pair of posteromesad discal setae (Fig. 2). *S. latipennis* is another member of the genus that, in fully mature adults, has at least the anterolateral areas of the pterothorax shaded or even dark brown. In fully mature females the abdominal terga are uniformly light brown to brown, although the legs are almost uniformly yellow, and the pronotum is distinctively paler or even yellow. This species is widely reported in countries of the Mediterranean region (zur Strassen, 2003), and is here newly recorded from Australia: two females have been studied taken from *Prunus* leaves in New South Wales [near Young in 1965 (ANIC), and near Leeton in 2001 (NSWO)].

***Scolothrips longicornis* Priesner 1926: 239**

Scolothrips acariphagus Jakhontov 1929: 273 (synonymised by zur Strassen 2003: 120)

The three members of the *S. longicornis* species-group, including *dilongicornis* and *takahashii*, cannot at present be distinguished from each other satisfactorily. However, these species can be distinguished readily from the *sexmaculatus* species-group because the sub-basal dark band on the fore wing fully extends to the anterior margin. Paratypes of both sexes of *S. dilongicornis* have been studied (in BMNH and SMF). Contrary to the original description of that species the sub-basal dark band on the fore wing does not fully include the hind margin of the wing, and these females cannot be distinguished satisfactorily from *longicornis*. This dark band is variable within populations of *longicornis*, and the posterior marginal vein of the fore wing is sometimes paler than the dark area itself. The paratype males of *dilongicornis* are micropterous, with the fore wing lobe scarcely longer than the thorax width, whereas the few males of *longicornis* seen from Europe are hemimacropterous with fore wings considerably longer than the thorax width. Priesner (1950) identified as *longicornis* two females collected by S.F. Bailey at Davis, California, and one of these has been compared with a series of 21 females, 10 males from almond trees at Esparto (near Davis), California (in UCD). The females in this series seem to be typical *longicornis*, but these Californian males are all fully macropterous (see *takahashii*).

***Scolothrips moundi* zur Strassen 1993: 365**

Described from the Cape Verde Islands, this distinctive species has no shaded markings anywhere on the body, and the fore wing clavus is shaded only at the extreme base. The fore wing has two strong dark bands that are complete across the fore wings. These dark bands are so strongly developed that the lack of dark markings on the body is not likely to be due to lack of maturity. The setae on the fore wing dark bands are weakly shaded, unlike the remaining major setae. This species is known only from the type specimens (in SMF and BMNH).

***Scolothrips ochoa* Mound, Tree & Goldarazena, 2010: 64**

This highly characteristic Australian species with compact antennal segments is presumably host-specific on *Raoiella*, a genus of mites in the family Tenuipalpidae. It is the only member of *Scolothrips* known to be a predator of mites that are not members of the Tetranychidae. The metanotal sculpture (Fig. 1) is similar to that of *asura*, and different from other members of the genus. The pronotal chaetotaxy is variable, because the holotype has a single small seta on the right hand side just in front of the posterior margin; one paratype has a pair of such setae (Fig. 1); the other paratypes have no setae in this position. It is not clear if these setae are homologous with the pronotal discal setae of the *sexmaculatus* species-group.

***Scolothrips pallidus* (Beach)**

Thrips pallida Beach, 1896: 226

Described from Iowa, the significance of this species remains unclear. Variation in body colour within a series of commercially reared *sexmaculatus* females from California is discussed below, and *pallidus* is possibly no more than a high temperature form of *sexmaculatus*.

***Scolothrips quadrimaculatus* Priesner 1933: 195**

Described from the Canary Islands, the two original females are not in the Senckenberg Museum. The character states that are used to distinguish *quadrimaculatus* in the key to European species (zur Strassen, 2003) are derived from the original description, and are here not considered reliable. Moreover, the key to species provided by Priesner (1950) also seems to have been constructed without access to the type specimens. The collection data quoted by Priesner for *quadrimaculatus* and for *lanzarotensis* are identical. It seems that the type material of all of the species described from the Canary Islands in that 1933 paper are missing, and in the absence of original specimens the name *quadrimaculatus* is here considered a *nomen dubium*.

***Scolothrips rhagebianus* Priesner 1950: 46**

Scolothrips indicus Priesner, 1950: 48. (synonymised by zur Strassen 1993: 366)

Mature adults of this Old World species can be distinguished from the New World species, *sexmaculatus*, by the pattern of pigmentation on the abdominal terga. In *rhagebianus*, most of these terga bear a distinctive pair of dark spots laterally (Fig. 8), and the shading on the median area of the terga usually does not extend to their posterior margins. The metascutum is usually much less pigmented than in *sexmaculatus*, but the metascutellum is dark. Isolated females that have not yet achieved mature colouration are difficult to distinguish from *sexmaculatus*, as are poorly mounted or damaged females; males can currently be identified only through association with females. Described originally from Egypt, *rhagebianus* is recorded from Sudan, Transvaal, Mauritius, and India (zur Strassen, 1993), and is here recorded as being widespread across Australia. At Shepperton, Victoria, it was found in 1968 in association with Tetranychidae on pear and peach trees. In New South Wales it has been found at Mittagong, Wilcannia and Broken Hill, particularly on native Poaceae. It has been taken from various plants in south east Queensland, and as a predator on spotted mites at Darwin, in the Northern Territory. In the north of Western Australia, at Kununurra, considerable populations were found in association with *Amblyseius* sp. (Phytoseidae) on the leaves of *Zea mays*, and among very large populations of *Eutetranychus orientalis* on *Citrus* leaves.

***Scolothrips sexmaculatus* (Pergande)**

Thrips sexmaculata Pergande, 1891: 539

The Lectotype of *sexmaculatus* (in USNM) is mounted ventral side uppermost, and the chaetotaxy of the pronotum is not visible. The series used by Priesner (1950) to redefine this species (in SMF) comprises five poorly preserved females mounted irregularly in a row on one slide, but the pair of pronotal posteromesad discal setae is visible on two of these females. A sample of 22 reared females of *sexmaculatus* was obtained in November 2010, through the courtesy of Mark Hoddle, from a commercial supplier of biocontrol agents in California. These females included several individuals with the tergal colour pattern described for *sexmaculatus* by Priesner (1950), a pattern that can also be seen on the Lectotype designated by Stannard (1968). In this pattern, the entire median area of terga II–IV, including their posterior margins, is uniformly shaded but with no lateral darker spots (Fig. 7). The shaded areas on terga V–VII of these females are more diffuse and incomplete medially. The metascutum is extensively shaded, and the metascutellum darker. This colour pattern distinguishes *sexmaculatus* clearly from *rhagebianus* – particularly if freshly collected specimens are examined.

Three New World species comprise the *sexmaculatus* species-group, but the significance of two of these, *hoodi* and *pallidus*, remains unclear. These three are distinguished by the presence and extent of shadings on the terga, and Hoddle *et al.* (2008) suggested that these colour differences might be due to environmental conditions during larval development, including temperature and the type of prey consumed. Specimens identified as *hoodi* (q.v.) have the body more extensively shaded, and the major setae slightly shorter (longest costal seta at fore wing sub-basal band no more than 100 microns, but in *sexmaculatus* varying 115–130 microns). At present, *hoodi* cannot otherwise be distinguished from the darkest individuals in the series of 22 reared females from California mentioned above. The palest individuals amongst this series have the terga almost without any shading, but each of them has at least the metascutellum shaded, and the pronotum bears paired spots laterally. That is, none of these specimens are as pale as individuals labelled as *pallidus* in the Bailey collection (UCD). In all three members of the *sexmaculatus* species-group, also in the closely related *rhagebianus*, the sub-basal dark band on the fore wing does not extend fully to the anterior margin of the wing. In contrast, this dark band fully extends to the costal margin of the wing in all other species of *Scolothrips*, including the *longicornis* species-group (although *tenuipennis* has no dark bands).

Described from California, the “six-spotted thrips” has been widely recorded, but no specimens identifiable as *sexmaculatus* have been seen from Australia. All previously published records of this species from Australia (Mound, 1996) are here considered to be based on misidentifications of the Old World species, *rhagebianus*.

***Scolothrips takahashii* Priesner 1950: 52**

Scolothrips priesneri Sakimura 1954: 357 **syn.n.**

The female holotype from Taiwan on which *S. takahashii* was based has been re-examined (in SMF) and compared with paratype macropterae of both sexes of *S. priesneri* from Hawaii (in SMF and UCD). These specimens are here considered to represent the same species and, although this is closely similar to *longicornis*, it differs in having the metascutellum shaded (as in *rhagebianus*) rather than clear yellow as in *longicornis*. The identity in California of a species that is represented in the collections at UCD by 21 females and 10 males from almond trees at Esparto remains in doubt. The males are all fully macropterous but, in contrast to *takahashii*, the metascutum lacks any shading. It is not possible at present to decide if thorax colour and male wing-length are stable characters that distinguish species in the *longicornis* species-group.

***Scolothrips tenuipennis* zur Strassen 1965: 30**

Described originally from a single male taken in the Canary Islands, both sexes have been studied (in SMF) from Cape Verde Islands (zur Strassen, 1993). Moreover, a single female (in ANIC) has been seen from Nairobi, Kenya, that seems likely to represent this unique species with its uniformly pale, non-banded, fore wings.

***Scolothrips uzeli* (Schille)**

Chaetothrips Uzeli Schille, 1911: 5

Based on females collected from *Juniperus* in Poland, this was described as the type species of the synonymic genus *Chaetothrips* Schille. It is now recognised as widespread in northern and central Europe on *Juniperus communis* (zur Strassen, 2003), presumably in association with some particular but unrecorded mite prey. It is a small species, with apterous males. In females, the body and wing shadings are particularly diffuse and often weak, but the colour of the fore wing clavus seems to be unique in the genus, dark to the apex but with the posterior margin pale. One out of 15 females studied from Netherlands, had a single pronotal posteromesad discal seta (in ANIC).

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